

MEASUREMENT OF SPRINKLER DROPLET SIZE

D. W. DeBoer, M. J. Monnens, D. C. Kincaid

ABSTRACT. Droplet distributions for rotating spray-plate sprinklers were measured using a laser technology and a flour methodology. In general, both methods produced comparable results. The flour method tended to produce d_{25} , d_{50} and d_{75} values that were on the average about 0.20 mm (about 15% of the d_{50} value) larger than laser values. However, the 0.20 mm difference is consistent with what would be expected when nozzle pressure differences used with the two methods are considered. Both methods can be used to estimate droplet distributions from rotary spray-plate irrigation sprinklers for practical field application purposes.

Keywords. Droplets, Sprinkler, Laser, Flour method, Distributions, Irrigation.

Information regarding droplet sizes from irrigation sprinklers has many beneficial uses. Large droplets can cause soil crusting problems because of kinetic energies associated with those droplets, while droplets at the smaller end of the spectrum can be subject to drift from an intended target area. In addition, d_{50} values (volume mean droplet diameter) are often used as a primary parameter to describe droplet distributions. Thus, such information can be of value to the sprinkler irrigation industry.

Droplet size data sets are expensive or time-consuming to obtain. Laser technology (Kincaid et al., 1996) can be used to acquire droplet distribution information in a relatively short time, but the capital investment is substantial or the equipment may not be readily available. In contrast, a labor-intensive method that uses baking flour as a droplet catchment medium was used extensively before the advent of the laser technology (Kohl, 1974). Researchers with limited capital budgets can substitute labor for capital by using the flour method.

Of course, the paramount question relates to the accuracy of both methods. One way to gain an insight into the matter is to perform a comparison study between the two methods. Researchers at South Dakota State University and the USDA-ARS in Idaho have been conducting droplet studies on various irrigation sprinklers during the past several years. Independent results for a common set of sprinklers and operating conditions were selected for the investigation.

The objective of this article is to report the findings of a comparison study in which the laser method and the flour

method were independently used to estimate droplet distributions for a set of rotating spray-plate sprinklers.

EXPERIMENTAL PROCEDURE

IRRIGATION SPRINKLERS

Rotating plate sprinklers (Rotator Series R-30 and Spinner Series S-30) manufactured by the Nelson Corporation (Walla Walla, Wash.) were used in the study. Water flows from a circular orifice in the form of a water jet that discharges onto a grooved spray plate, inducing plate rotation. Grooves on the plate split the discharge jet into smaller jets. Components of the sprinklers are illustrated in Figure 1. While both sprinklers are similar in structure and operation, the Rotator spray plate rotates from 1 to 10 rpm (depending on nozzle discharge and velocity) producing water jets, while the Spinner spray plate rotates from 100 to 600 rpm producing droplets.

Nominal nozzle pressures and other sprinkler details are presented in Table 1. Spray plates with four and six grooves were used in the investigation along with 4.8, 6.4, and 9.5 mm (3/16, 1/4, and 3/8 in.) nozzle diameters. Comparable spray plates were employed for all tests. A 9.9-mm nozzle was used in the flour method tests, instead of the 9.5-mm nozzle used for the laser method investigation. An analysis of flour method data indicated that changes in nozzle pressure had a statistically significant influence on d_{50} values but nozzle diameter differences had a minimal influence. Nominal nozzle pressures of 100 and 200 kPa (14.5 and 29.0 psi) were used. However, actual values for the laser method were 108 and 206 kPa, while the flour method values were closer to 96 and 196 kPa. Results from a companion study (not reported in this article) indicated that the flour method pressure values used in the study would be expected to produce d_{50} data that were about 0.2 mm larger than d_{50} data associated with the laser method pressure values.

Manufacturer-recommended nozzle diameters and pressures for the two sprinklers are shown in Figures 2 and 3. Tests conducted on the Rotator sprinklers were within recommended conditions except for the 9.5-mm nozzle diameter. The 200-kPa nozzle pressure was substantially above the maximum recommended pressure for the Spinner sprinkler, which tended to produce smaller droplets than desired for field conditions but which did not adversely affect droplet measurement comparisons.

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The authors are Darrell W. DeBoer, ASAE Member Engineer, Professor, Dept. of Agricultural and Biosystems Engineering, South Dakota State Univ., Brookings, S. Dak.; Micheal J. Monnens, Program Engineer, Engineering Extension, South Dakota State Univ., Brookings, S. Dak.; and Dennis C. Kincaid, ASAE Member Engineer, Agricultural Engineer, USDA-Agricultural Research Service, Kimberly, Idaho. Corresponding author: Darrell W. DeBoer, Dept. of Agricultural and Biosystems Engineering, PO Box 2120, South Dakota State Univ., Brookings, SD 57007; phone: (605) 688-5141; fax: (605) 688-6764; e-mail: darrell_deboer@sdstate.edu.

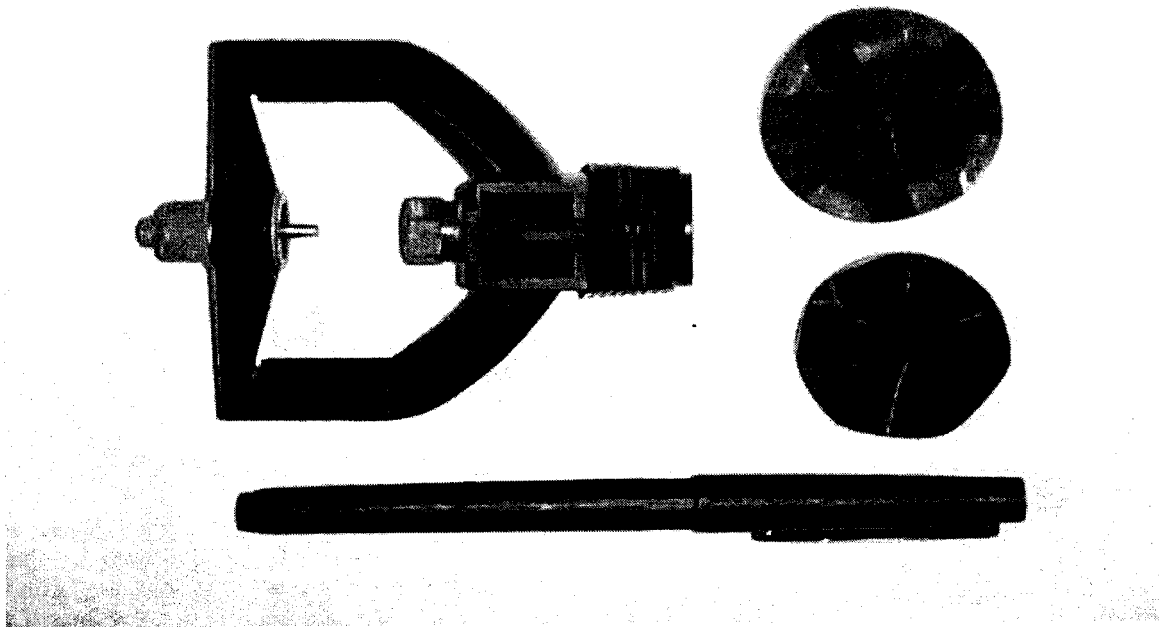


Figure 1. Rotating spray-plate sprinkler assembly and components.

Table 1. Sprinklers and operating conditions used in the study.

| | ID* | Sprinkler | Spray Plate | Nozzle Pressure (kPa) | Nozzle Diameter (mm) |
|----|--------|-----------|-------------|-----------------------|----------------------|
| 1 | R42048 | Rotator | 4 groove | 200 | 4.8 |
| 2 | R42064 | Rotator | 4 groove | 200 | 6.4 |
| 3 | R62048 | Rotator | 6 groove | 200 | 4.8 |
| 4 | R61064 | Rotator | 6 groove | 100 | 6.4 |
| 5 | R62064 | Rotator | 6 groove | 200 | 6.4 |
| 6 | R62095 | Rotator | 6 groove | 200 | 9.5 (9.9) |
| 7 | S61048 | Spinner | 6 groove | 100 | 4.8 |
| 8 | S62048 | Spinner | 6 groove | 200 | 4.8 |
| 9 | S61064 | Spinner | 6 groove | 100 | 6.4 |
| 10 | S62064 | Spinner | 6 groove | 200 | 6.4 |

*R = Rotator, 4 = 4 groove, 20 = 200 kPa and 48 = 4.8mm

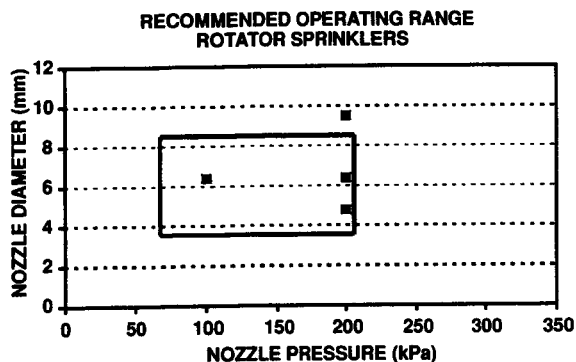


Figure 2. Manufacturer's recommended minimum and maximum nozzle diameters and operating pressures for Rotator sprinklers within the box. Symbol positions indicate nozzle sizes and pressures used in the study.

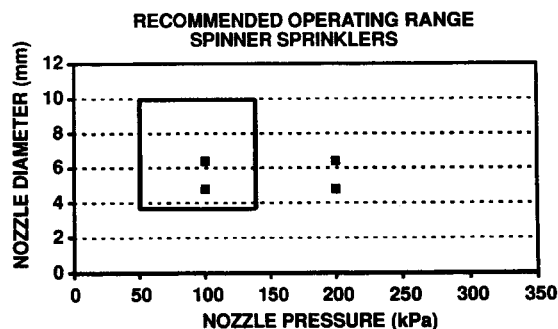


Figure 3. Manufacturer's recommended minimum and maximum nozzle diameters and operating pressures for Spinner sprinklers within the box. Symbol positions indicate nozzle sizes and pressures used in the study.

Sprinklers were positioned 3.0 m above the droplet measurement plane for the laser method tests and 2.5 m for the flour method tests. This elevation difference did not affect droplet size distributions from the sprinklers but would be expected to have some influence on the radius of water throw and the positioning of droplet sizes along the wetted radii.

DROPLET SIZE MEASUREMENTS

Laser-optical measurements of droplet diameters were made with a Particle Measuring System (Boulder, Colo.) Model GBPP-100S that has the ability to measure droplet sizes from 0.2 to 13 mm in 0.2-mm increments. Details of

the experimental procedure for the measurement of sprinkler droplets by the laser method are given in Kincaid et al. (1996) and Solomon et al. (1991). A total of 10,000 droplets were measured at each radial position.

The flour method of Laws and Parsons (1943) as adapted by Kohl (1974) was used to obtain the independent droplet data set for comparison purposes. Measured droplet sizes ranged from 0.33 to 5.95 mm in 0.08-mm increments for the smallest droplets to a 1.01-mm increment at the upper end of the measurement range. Relatively few droplets were measured, as compared to the laser study, because the flour catchment pans could only be exposed to the irrigation water for a short time to insure individual droplet integrity.

Measurements were made at 1-m radial intervals to 8 m for the laser method and at 1-m intervals to the edge of the wetted area for the flour method. However, smaller intervals were used at the outer edge of the wetted area for the flour method where water application rate variations were large over small changes in radial distances. Composite droplet size distributions for each sprinkler test were developed from area-weighted droplet measurements. Only one unrepliated set of test data was collected.

RESULTS

Several issues with regard to the experimental procedures used in this study need to be considered. First, commercial-run sprinklers were employed in the tests with different sets of sprinklers used at each study site. Second, operating conditions were controlled but were slightly different for each measurement method. In particular, operating pressures were approximately the same but were not identical. Third, the number of droplets measured by each method was vastly different: The flour method had a total droplet catch in the thousands, while the laser method dealt with droplet numbers in the hundreds of thousands.

Both measurement methods produced similar results, as illustrated in Figures 4 through 13. Two data sets with the largest differences (Figures 4 and 7) are representative of operational conditions that produced the largest droplet sizes and the flattest distribution relationships. One laser data distribution (Figure 10) has an uncharacteristic shape over the 1- to 2-mm diameter range that makes a valid comparison questionable for this sprinkler data set. The remaining seven data sets show good overall agreement between the two methods, with the flour method tending to indicate the presence of fewer small droplets than the laser method data would suggest.

A summary of d_{10} , d_{25} , d_{50} , d_{75} , and d_{90} values to the nearest 0.1 mm for both measurement methods and the differences between method values is presented in Table 2. Results for sprinkler S61048 (Figure 10) are not included because of the questionable laser values. Differences between the d_{10} values ranged from 0.0 to 0.2 mm (a positive value means that flour values are greater than laser values) and averaged 0.13 mm. Similar differences also are noted for

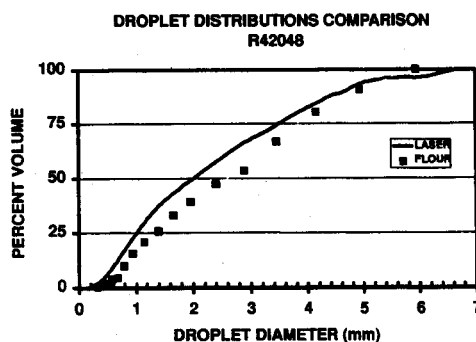


Figure 4. Comparison of droplet distributions from the laser method and the flour method for sprinkler R42048.

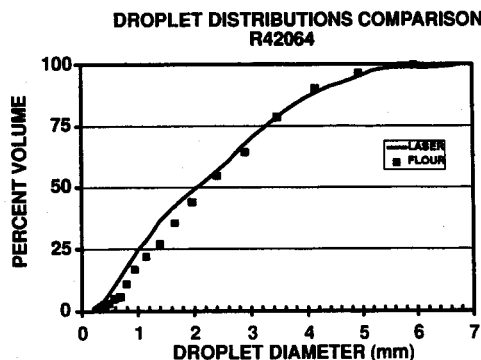


Figure 5. Comparison of droplet distributions from the laser method and the flour method for sprinkler R42064.

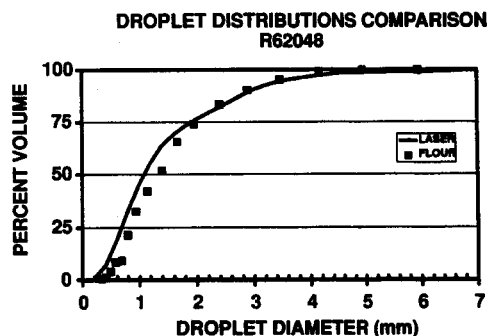


Figure 6. Comparison of droplet distributions from the laser method and the flour method for sprinkler R62048.

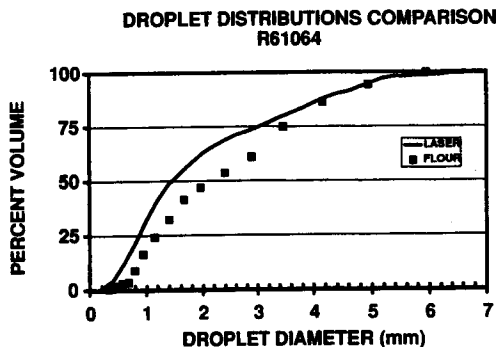


Figure 7. Comparison of droplet distributions from the laser method and the flour method for sprinkler R61064.

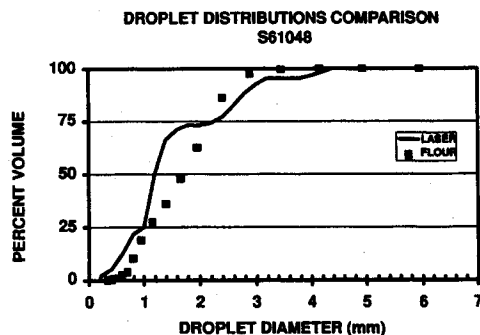


Figure 10. Comparison of droplet distributions from the laser method and the flour method for sprinkler S61048.

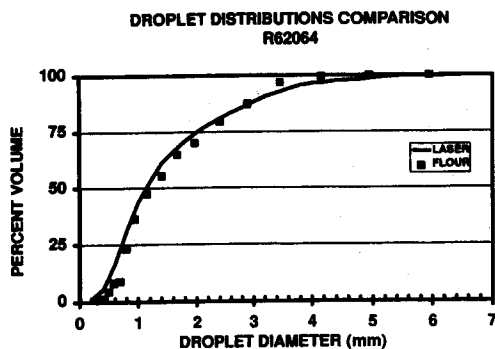


Figure 8. Comparison of droplet distributions from the laser method and the flour method for sprinkler R62064.

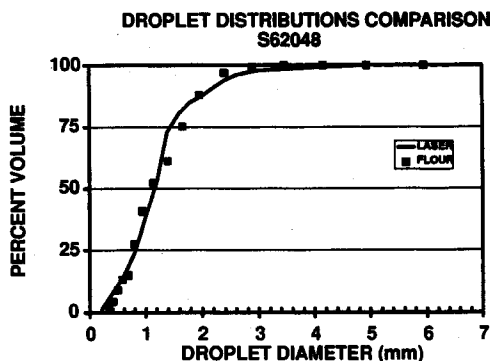


Figure 11. Comparison of droplet distributions from the laser method and the flour method for sprinkler S62048.

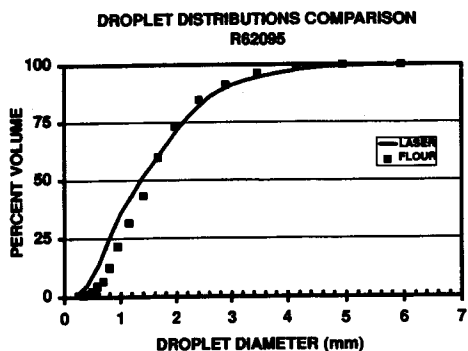


Figure 9. Comparison of droplet distributions from the laser method and the flour method for sprinkler R62095.

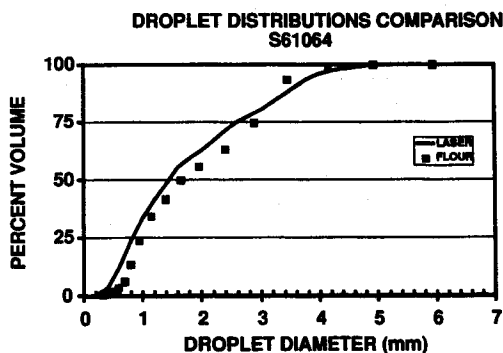


Figure 12. Comparison of droplet distributions from the laser method and the flour method for sprinkler S61064.

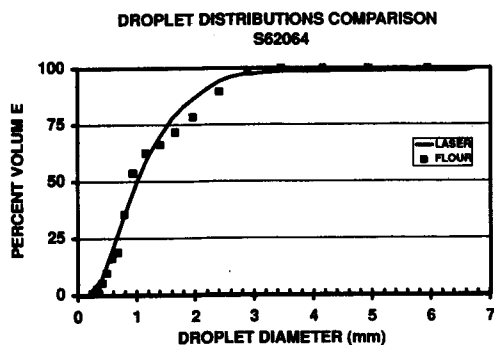


Figure 13. Comparison of droplet distributions from the laser method and the flour method for sprinkler S62064.

d_{25} values with a mean of 0.19 and a range of 0.0 to 0.3 mm. The d_{50} data sets had larger and more varied differences than any of the other difference data sets. Differences ranged from -0.1 to 0.7 mm with a mean of 0.18 mm. The d_{75} data set also had large difference variations ranging from -0.1 to 0.5 mm but with a mean of about 0.20 mm while the d_{90} data had a range of -0.2 to 0.2 with a mean of -0.06 mm.

On the average, the flour data tend to be from 0.15 to 0.20 mm larger than the laser data. This difference is consistent with what would be expected (for d_{50} values based on an unreported analysis) when the nozzle pressure differences

used in the independent studies are considered. Based on the limited data sets presented in this article, a representative estimate for laser values can be obtained by simply reducing flour data values by 0.2 mm. This 0.2 mm represents about 20% of average d_{25} flour values, 13% of d_{50} values, and 8% of d_{75} values.

When one considers the lack of rigorous experimental protocol, droplet size distributions from the two measurement methods are similar enough to each other to support the conclusion that either method can be used to estimate droplet distributions from rotary spray-plate irrigation sprinklers. The laser and flour methods do not produce identical results, but they both produce comparable and reasonable results that are of sufficient quality for practical field application purposes.

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Table 2. Droplet sizes (mm) for 10, 25, 50, 75 and 90% of sprinkler discharge volumes and differences (Δ) between the two methods.

| Sprinkler | d_{10} | | | d_{25} | | | d_{50} | | | d_{75} | | | d_{90} | | |
|-----------|----------|-------|----------|----------|-------|----------|----------|-------|----------|----------|-------|----------|----------|-------|----------|
| | Laser | Flour | Δ | Laser | Flour | Δ | Laser | Flour | Δ | Laser | Flour | Δ | Laser | Flour | Δ |
| R42048 | 0.6 | 0.8 | 0.2 | 1.0 | 1.3 | 0.3 | 2.0 | 2.4 | 0.4 | 3.5 | 3.8 | 0.3 | 4.7 | 4.8 | 0.1 |
| R42064 | 0.6 | 0.8 | 0.2 | 1.0 | 1.3 | 0.3 | 2.0 | 2.2 | 0.2 | 3.3 | 3.3 | 0.0 | 4.3 | 4.1 | -0.2 |
| R62048 | 0.5 | 0.6 | 0.1 | 0.7 | 0.9 | 0.2 | 1.0 | 1.2 | 0.2 | 1.9 | 2.0 | 0.1 | 3.0 | 2.9 | -0.1 |
| R61064 | 0.6 | 0.8 | 0.2 | 0.9 | 1.2 | 0.3 | 1.5 | 2.2 | 0.7 | 3.0 | 3.5 | 0.5 | 4.4 | 4.5 | 0.1 |
| R62064 | 0.5 | 0.6 | 0.1 | 0.7 | 0.8 | 0.1 | 1.2 | 1.2 | 0.0 | 2.0 | 2.2 | 0.2 | 3.2 | 3.0 | -0.2 |
| R62095 | 0.5 | 0.7 | 0.2 | 0.8 | 1.0 | 0.2 | 1.4 | 1.5 | 0.1 | 2.2 | 2.1 | -0.1 | 2.9 | 2.8 | -0.1 |
| S62048 | 0.5 | 0.5 | 0.0 | 0.8 | 0.8 | 0.0 | 1.2 | 1.1 | -0.1 | 1.4 | 1.7 | 0.3 | 2.2 | 2.1 | -0.1 |
| S61064 | 0.6 | 0.7 | 0.1 | 0.8 | 1.0 | 0.2 | 1.4 | 1.6 | 0.2 | 2.6 | 2.9 | 0.3 | 3.6 | 3.4 | -0.2 |
| S62064 | 0.4 | 0.5 | 0.1 | 0.6 | 0.7 | 0.1 | 1.0 | 0.9 | -0.1 | 1.6 | 1.8 | 0.2 | 2.2 | 2.4 | 0.2 |
| Mean | | | 0.13 | | | 0.19 | | | 0.18 | | | 0.20 | | | -0.06 |